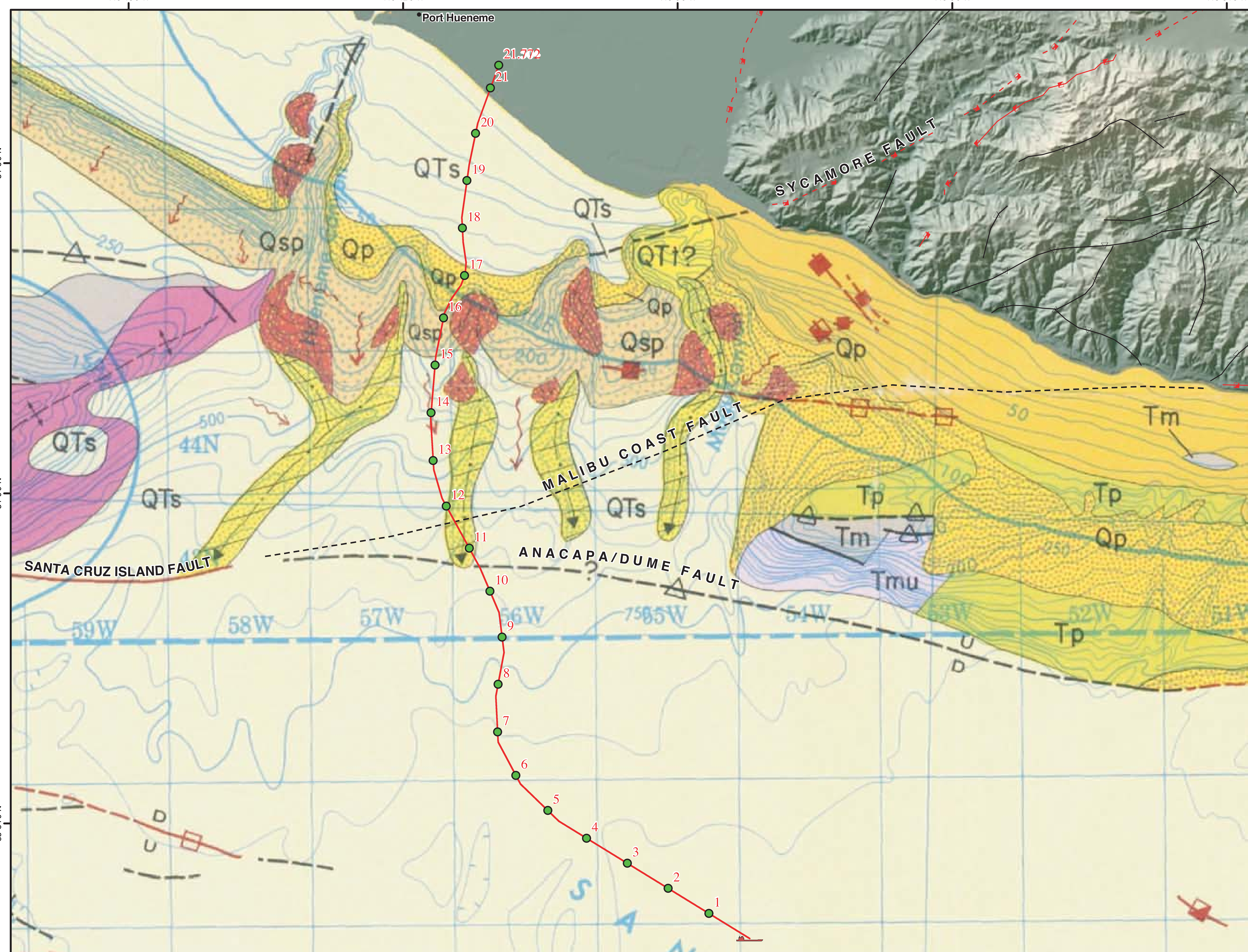


Cabrillo Port Mooring Point

Milepost

Cabrillo Port Pipeline Route

Q — Unconsolidated deposits of Quaternary age, includes ponded sediments

Qp — Uncosolidated marine shelf and slope deposits of late Pleistocene age

Qsp — Sediments that may correlate with the San Pedro Formation

QTs — Undifferentiated sediments and sedimentary rocks of Quaternary and Tertiary (Pliocene and Miocene) age

QTt — Undifferentiated terrace deposits of Quaternary and late Tertiary (?) age

Tp — Undifferentiated sedimentary rocks of Pliocene age

Tm — Undifferentiated sedimentary rocks of Miocene age

Tmv — Volcanic rocks of Miocene age

Tmu — Undifferentiated volcanic and sedimentary rocks of Miocene age

Faults and Folds: Solid where well defined, dashed where inferred, queried where uncertain. Barbs shown on upper plate of thrust fault. Where fault offsets sea floor, age symbol is shown on bar on downthrown side. Where age was determined, age symbol is shown astride fault and relative offset is shown by "D" and "U" on downthrown and upthrown sides. Ages of faults are indicated as follows, all faults considered active or potentially active shown in red. Solid arrow on anticlines and synclines indicates direction of axial plunge.

Cuts strata of Holocene age — Cuts strata of Pleistocene age

Cuts strata of Quaternary age — Cuts strata of Pliocene age

Cuts Miocene or older strata

Faults

Anticline

Syncline

Filled channel: Dash-dot line marks axis, arrow indicates direction of paleo-sediment transport. Channel boundary solid where well-defined, dashed where inferred.

Landslides: Solid where well defined, dashed where inferred, queried where uncertain.

Creep (noted on single survey line): arrow indicates apparent direction of sediment movement

Slump — Oil and/or gas seep — Acoustic anamoly

Note: Location of some faults are estimated

Sources: CGS Mid-Southern CA Continental Margin Map 2A, USGS NED, GNIS

2 1 0 2 Miles

NAD27 UTM Zone 11

Cabrillo Port LNG Deepwater Port
EIS/EIR, 2004

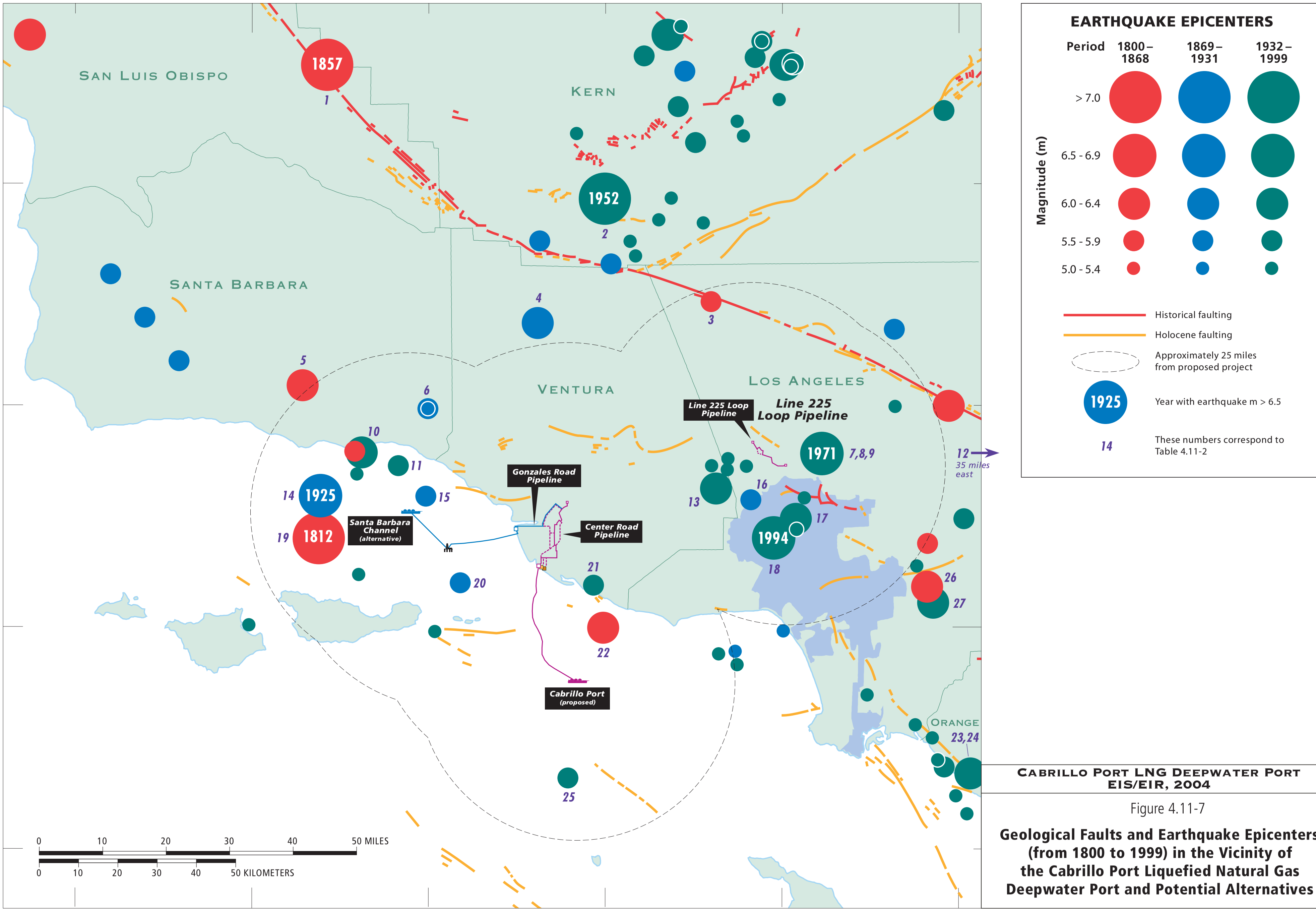
Figure 4.11-6

Local Offshore Geologic Map

Source: Entrix, 2004

u:\gis\entrix\3068505\map\bhplng_capt_localoffshgeol_17i11i_02.mxd 5/16/2003 7:19:53 PM zder

Reference: *Map Sheet 49: Epicenters of and Areas Damaged by M ≥ 5 California Earthquakes, 1800 – 1999*, California Department of Conservation, 2000



Cabrillo Port LNG Deepwater Port EIS/EIR, 2004

Figure 4.11-7

Geological Faults and Earthquake Epicenters (from 1800 to 1999) in the Vicinity of the Cabrillo Port Liquefied Natural Gas Deepwater Port and Potential Alternatives

001883.CA04.01.01.e (BHP Cabrillo Port folder) 10/13/2004

Table 4.11-1 lists known active and potentially active faults within 25 miles (40 km) of the Project, whereas Table 4.11-2 lists historical earthquakes greater than M 5.5 with epicenters within 25 miles (40 km) of the site and their associated faults. Large earthquakes that were within about 80 miles (129 km) are also listed.

Table 4.11-1 Recorded Earthquakes >4.5 Magnitude near Project Site

Date	Name of Associated Fault or Zone	Richter Scale Magnitude	Epicenter from Project
01/10/1857	San Andreas Fault	5.6	*23 miles (37 km) NNW from Line 225 Pipeline Loop*
04/04/1893	Santa Susana Thrust Zone/Simi	5.5	*15 miles (24 km) S from Line 225 Pipeline Loop*
05/19/1893	Unidentified	5.8	*18 miles (29 km) WSW from Center Road Pipeline route*
12/14/1912	Offshore fault	5.0	*15 miles (24 km) SSE from Center Road Pipeline route*
02/18/1926	Oak Ridge Fault	5.5	*20 miles (32 km) NW from Center Road Pipeline route*
08/05/1930	Anacapa/Dume Fault	5.2	*18 miles (29 km) WNW from Center Road Pipeline route*
07/01/1941	Pitas-Point Ventura	5.5	*22 miles (35 km) WNW from Center Road Pipeline route Alternative 2*
8/23/1952	San Andreas Fault	5.0	*21 miles (34 km) ENE from Line 225 Pipeline Loop*
02/09/1971	San Fernando Fault	6.6	*6 miles (10 km) E from Line 225 Pipeline Loop*
02/21/1973	Anacapa/Dume Fault	5.3	*11 miles (18 km) SSW from Center Road Pipeline route*
02/21/1973	Malibu Coast Fault	5.9	*9 miles (14.5 km) SSE from Center Road Pipeline route*
08/06/1973	Anacapa/Dume Fault	5.0	*22 miles (35 km) WSW from Center Road Pipeline route*
01/17/1994	Northridge Fault	6.7	*12 miles (19 km) S from Line 225 Pipeline Loop*
01/17/1994	Northridge (aftershocks)	6.0	*22 miles (35 km) ESE from Center Road Pipeline route*
Note: Epicenters of identified earthquakes were within 25 miles (40 km) of the Project. Sources: Real et al. (1978), Toppozada et al. (2000), Yerkes (1985).			

Table 4.11-2 Recorded Earthquakes >5.5 Magnitude within 25 Miles (40 km) of the Project or Large Quakes within ~80 Miles (129 km), 1800 to 1999

Map No.[1]	Date	Estimated Magnitude[2]	Quake Name and/or Fault Name	Distance and Direction from Project to Epicenter
1	01/09/1857	7.9	Ft. Tejon/San Andreas Fault	~80 miles (129 km) WNW of Center Rd. and 225 Pipeline Loop (Surface rupture 23 miles (37 km) from line 225 pipeline loop)
2	07/21/1952	7.3	Kern Co. quake, White Wolf Fault	~45 miles (72 km) NW of Line 225 Pipeline Loop
3	01/10/1857	5.6	San Andreas Fault	~20 miles (32 km) NW of 225 Pipeline Loop
4	09/05/1883	6.3	San Andreas Fault	~40 miles (64 km) WNW of Line 225 Pipeline Loop
5	01/01/1821	6.3	unknown	~45 miles (72 km) WNW of Center Rd. Line
6	06/29/1926	5.5	unknown	~28 miles (45 km) from Center Rd. route
7	02/09/1971	6.6	Sylmar Quake, San Fernando Fault	~7 miles (11 km) NE of Line 225 Pipeline Loop
8	02/09/1971	5.8	Sylmar aftershock	~7 miles (11 km) NE of Line 225 Pipeline Loop
9	02/09/1971	5.8	Sylmar aftershock	~7 miles (11 km) NE of Line 225 Pipeline Loop
10	08/13/1978	6.0	Santa Barbara	~33 miles (53 km) WNW of Center Rd. route
11	07/01/1941	5.9	Pitas-Point Ventura fault	~25 miles (40 km) WNW from Center Rd. route
12	12/08/1812	7.5	San Andreas Fault	~50 miles (80 km) E of Line 225 Pipeline Loop
13	01/17/1994	6.0	Northridge aftershock	~10 miles (16 km) SW of Line 225 Pipeline Loop
14	06/29/1925	6.8	Santa Barbara Channel	~38 miles (61 km) W of landfall
15	02/18/1926	5.5	Oak Ridge Fault	~20 miles (32 km) W of Center Rd.
16	04/04/1893	5.8	Santa Suzana Thrust Zone-Simi	~5 miles (8 km) S of Line 225 Pipeline Loop
17	01/17/1994	6.2	Northridge aftershock	~7 miles (11 km) SE of Line 225 Pipeline Loop
18	01/17/1994	6.7	Northridge Quake and Fault	~12 miles (19 km) S of Line 225 Pipeline Loop
19	12/21/1812	7.1	Santa Barbara Channel	~36 miles (58 km) W of offshore pipeline
20	05/19/1893	5.8	unknown	~12 miles (24 km) W of offshore pipeline
21	02/21/1973	5.9	Pt. Mugu, Malibu Coast Fault	~9 miles (14 km) E of landfall

Table 4.11-2 Recorded Earthquakes >5.5 Magnitude within 25 Miles (40 km) of the Project or Large Quakes within ~80 Miles (129 km), 1800 to 1999

Map No.[1]	Date	Estimated Magnitude[2]	Quake Name and/or Fault Name	Distance and Direction from Project to Epicenter
22	09/24/1827	6.0	Anacapa-Dume Fault	~8 miles (13 km) E of offshore pipeline
23	03/11/1933	6.4	Long Beach	~60 miles (96 km) E of FPSU
24	03/11/1933	5.5	Long Beach aftershock	~60 miles (96 km) E of FPSU
25	09/04/1981	5.9	Santa Cruz-Catalina Escarpment	~14 miles (18 km) S of FPSU
26	07/11/1855	6.0	unknown	~30 miles (48 km) ESE of Line 225 Pipeline Loop
27	10/01/1987	6.0	unnamed	~33 miles (53 km) ESE of Line 225 Pipeline Loop

Notes:

Data are from Toppozada et al. 2000. All recorded quakes > magnitude 5.5 are listed.

1- Map number refers to map of Figure 4.11-1.

2-In southern California the Caltech Seismological Laboratory was established in 1932. Prior to 1932, the location and magnitude are estimates only.

Due to the frequency of earthquakes in the Project region, it should be expected that during the design life of the Project, an earthquake would occur that could cause damage to improperly designed structures. The USGS has estimated a probability of about 35 percent for an earthquake of M 6.5 or larger within 30 miles (48 km) of the offshore floating LNG facilities over the next 30 years. This probability increases to about 60 percent for some of the onshore pipeline locations (Ross et al. 2004). Also, due to its potential to produce a great earthquake (>M 8.0), resulting in large, long-period ground motions at the Project site, the San Andreas Fault is also considered to be of significance. The San Andreas Fault is located as close as 20 miles (32 km) to the Line 225 Pipeline Loop segment and about 50 miles (80.5 km) from where the Project pipeline comes ashore.

Since periodic earthquakes accompanied by surface displacement can be expected during the Project life, the effects of strong ground shaking, mass movement, and fault rupture are of primary concern to the safe operations of the proposed pipeline and associated facilities.

Fault Rupture

Ground surface displacement, or rupture, caused by an earthquake is a major consideration in the design of pipeline crossings of active faults. The State has mapped known faults in inhabited areas as part of the Alquist-Priolo Earthquake Fault Zoning Act. The known faults extending to or near the ground surface in the onshore Project and Alternative areas are relatively well defined. The Center Road Pipeline Alternatives and Line 225 Pipeline Loop routes appear to cross known active or potentially active faults that are capable of surface rupture, and therefore, fault rupture is a direct concern to the Project. The Center Road Pipeline Alternatives cross a mapped Alquist-Priolo fault zone at approximately MP 12.6.

The active San Gabriel Fault, or an associated fault, may be crossed by the Line 225 Pipeline Loop between Loop MP 0.0 and 0.25 and again near MP 7.0 (Figure 4.11-5). However, the more detailed Alquist-Priolo Fault Zone maps do not show the pipeline as crossing the fault, but within about 0.5 mile (0.8 km) of the fault. These possible fault crossings will be confirmed by a geotechnical investigation by the applicant prior to pipeline installation. Offshore, there is no evidence of recent fault rupture along the pipeline routes, but some faults could be considered potentially active and the pipelines likely cross over buried faults. For example, the offshore Project route crosses the projected Dume Fault at approximately MP 5 and the Malibu Coast Fault at approximately MP 6.5.

Ground Shaking

Ground shaking is the earthquake effect that results in the vast majority of damage. Strong shaking from an earthquake can result in landslides and turbidity flows, ground lurching, structural damage, and liquefaction. Strong ground shaking can also set into motion other hazards such as fire; disruption of essential facilities and systems, e.g., water, sewer, gas, electricity, transportation, communications, irrigation, and drainage systems; releases of hazardous materials; or flood inundation as a result of dam or water tank failure.

An internal California Department of Transportation (CalTrans) report estimated the maximum horizontal acceleration on rock or stiff soil sites that could be produced from the maximum credible earthquake along major active faults. The report indicates that the Project and Alternative sites are located in an area with the potential to generate a peak ground acceleration (Pga) between 0.5 and 0.7 times the gravitational acceleration (Mualchin and Jones 1992 as reported in Entrix, May 2004).

The California Geological Survey (CGS) has conducted calculations to estimate Pga as a fraction of the acceleration due to gravity (g). Structures can then be designed to withstand these ground motions. The Pga is calculated for firm rock, soft rock, and alluvium (which has the highest ground motion). CGS states that the calculated Pga value has a 10 percent probability of being exceeded in 50 years. Three locations along the Project route were selected and the calculated Pga in alluvium ranged from 0.467 to 0.501 g (CGS 2004). This compares favorably with the CalTrans report listed above.

Mass Movement

Damage to pipelines and/or other facilities could occur due to mass movement of soil. Mass movement includes landslides, liquefaction, subsidence, sand migration, or turbidity currents. The ground shaking from an earthquake could cause loose sediments found on slopes to move. Onshore, seismic hazard zone maps show that the Center Road Pipeline and alternate routes occur almost entirely within areas that may be subject to liquefaction (CGS 2004). The Line 225 Pipeline Loop encounters areas that are considered as having landslide potential in MP 0 to 3, and over the last 0.5 mile (0.8 km) the areas in-between are considered as having liquefaction potential (CGS 2004b). Offshore, the route was selected to be in areas with as gentle slopes as possible and to avoid active offshore canyon areas (Figures 4.11-2 and 4.11-6). However, the potential for slides and turbidity currents still exists but is much lower since these areas were avoided.

Liquefaction

Liquefaction is the phenomenon in which saturated granular sediments temporarily lose their shear strength during periods of strong ground shaking, e.g., such as that caused by an earthquake. The area considered to have the highest liquefaction potential along the offshore part of the Project is on the shallow shelf near the onshore landing. It is in that location that the thickest deposits of potentially liquefiable material are expected. (Fugro March 2004).

Most of the onshore parts of the pipelines are in areas that are considered to have liquefaction potential due to the granular soils and shallow water table.

Subsidence and Settlement

Land surface subsidence can be induced by both natural and human phenomena. Natural phenomena include: subsidence from tectonic deformations and seismically induced settlements; soil subsidence due to consolidation, hydrocompaction, or rapid sedimentation; subsidence due to oxidation or dewatering of organic-rich soils; and subsidence related to subsurface activities. Subsidence or settlement related to human activities includes subsidence caused by a decrease in pore pressure due to the withdrawal of groundwater or petroleum products.

There are two types of settlement: compaction and consolidation. Compaction, as herein defined, occurs in dry or moist cohesionless sediments, whereas consolidation occurs in water-saturated sediments. For both types of settlement, vibratory motion causes granular sediments to be rearranged into a denser packing. The net result is reduction of void space, a corresponding reduction of the overall thickness of the cohesionless materials, and possible settlement of the ground surface. If the soil is dry, the settlement (compaction) is concurrent with the earthquake motion. Consolidation is a relatively slow process, compared to compaction, and is a function of the permeability of the soil.

Seismically induced differential settlement generally occurs in loose, granular soils. Cohesive or clay soils and sediments exhibit little or no settlement as a direct result of ground shaking. Theoretically, little damage to a structure (such as the Project pipeline) would occur if the soil settles uniformly. Totally uniform settlement is rare and differential settlement can cause considerable damage to improperly engineered structures. Results of a study by Sprotte and Johnson (1976, as reported by Entrix, May 2004) indicate that the potential for seismically induced differential settlement of Holocene sediments in the Project area is high.

The most common cause of man-induced subsidence is the withdrawal of fluids, including oil, gas, and water. Subsidence due to groundwater extraction withdrawal is the most extensive type of subsidence in California (City of Oxnard et al. 1980; California Division of Mines and Geology [CDMG] 1973). A large area of the Oxnard Plain has experienced subsidence. This area has been monitored by the United States Coast and Geodetic Survey since 1930 and has experienced as much as 0.04 to 0.05 feet (0.01 to 0.02 m) of subsidence per year (City of Oxnard et al. 1980). A single point located at Hueneme Road and Highway 1 dropped 1.5 feet (0.5 m) in 21 years. Records from 1968 show a dozen benchmarks that have settled 1 foot in a 15- to 20-year period. The current level of subsidence is relatively small and may be observed in the Project area by other effects such as beach erosion and deposition. However, subsidence will probably continue and the rate and amount could increase if extraction of fluids from the area is maintained at its current level, or increases.

No large-scale local subsidence has been reported in the City of Santa Clarita, near the proposed the Line 225 Pipeline Loop due to groundwater or oil extraction (City of Santa Clarita General Plan, Safety Element). Much of the city is located over consolidated sediments that are not very prone to subsidence. The subsidence potential associated with groundwater or oil removal within the city is low (City of Santa Clarita General Plan, Safety Element 1991).

There is some risk of a change in elevation as a result of vertical movement along the San Gabriel Fault. Although this fault is generally described as being strike-slip, it is common to have localized uplift or downdropping along strike-slip faults. Therefore, it is possible to have some localized, seismically induced subsidence within the Line 225 Pipeline Loop vicinity (City of Santa Clarita General Plan, Safety Element 1991). Movement along a strike-slip fault is predominately parallel to the face of the fault, i.e., the movement is to the side. A normal or reverse fault has the predominate movement up or down relative to the face of the fault.

Tsunamis/Seiche

Tsunamis are sea waves generated by rapid displacement of a large volume of sea water, resulting from submarine vertical faulting or warping of the sea floor, from large-scale submarine slides, or from volcanic eruptions in or near ocean basins. In the open ocean, these waves have a very long period and wavelength; i.e., the waves are spaced far apart and travel at speeds up to hundreds of miles per hour. As a tsunami approaches the shoreline, the speed of the wave decreases and the wave height increases, resulting in potentially destructive effects. Historical records indicate that the severity of tsunami-generated damage varies greatly depending on factors such as coastal topography, the existence of offshore islands, and the direction of the incoming waves.

Although most coasts of the Pacific Ocean have a long history of tsunami-caused death and destruction, tsunami damage to coastal California has been relatively slight (McCulloch 1985, as reported in Entrix 2004). The only tsunami to cause appreciable damage and loss of life along the California coast occurred as a result of the 1964 Alaska earthquake; most of the damage and loss of life occurred along the northern California coast. Several small tsunamis have been recorded in the Project area over the last 200 years, each generally accounting for run-up wave heights of less than 3 to 4 feet (0.9 to 1.2 m).

However, the potential exists for a future major tsunami in the Project area. Locally generated tsunamis could result from significant displacement of submarine faults or from submarine slides. A preliminary appraisal of the potential for locally generated tsunamis suggests that wave run-up heights as great as 12 to 18 feet (3.7 to 5.5 m) could be caused by sea-floor faulting in the Santa Barbara Channel (McCulloch 1985). According to the Oxnard General Plan, the Center Road Pipeline Route is susceptible to tsunamis between approximately MP 0.0 and MP 1.6.

Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) provides estimated tsunami run-up values for the Ports of Los Angeles, Long Beach, and Hueneme. For the Ports of Los Angeles and Long Beach, the 100-year return period is 8.0 and the 500-year return period is 15.0. For the Port of Hueneme, the 100-year return period is 11.0 and the 500-year return period is 21.0 (CSLC 2004).

Seiches are oscillations in an enclosed body of water, such as a lake, that may be caused by an earthquake. Most seiches are created when landslides fall into a body of water and displace a large volume of water. There are no enclosed bodies of water in the Project and Alternative vicinity.

4.11.1.3 Paleontological Resources

Paleontological resources are the mineralized (fossilized) remains of prehistoric plants and animals, as well as the mineralized impressions (trace fossils) left as indirect evidence of the form and activity of such organisms. These resources are considered to be non-renewable resources.

Paleontologic sensitivity is the potential for a geologic unit to produce scientifically significant fossils, as determined by rock or unconsolidated material type, past history of the rock or unconsolidated material unit in producing fossil materials, and fossil sites that are recorded in the unit. A paleontologic sensitivity rating is derived from fossil data from the entire geologic unit, not just from a specific survey area. Offshore areas are generally not considered potential sources of paleontological resources based on their inaccessibility.

A three-fold classification of sensitivity, labeled as high, low, and indeterminate, is used in California and recommended by the Society of Vertebrate Paleontology (SVP). The classification is defined as follows:

- *High Sensitivity* – Indicates fossils are currently observed on site, localities are recorded within the study area, and/or the unit has a history of producing numerous significant fossil remains.
- *Low Sensitivity* – Indicates significant fossils are not likely to be found because of random fossil distribution pattern, extreme youth of the rock unit, and/or the method of rock formation, such as alteration by heat and pressure.
- *Indeterminate Sensitivity* – Unknown or undetermined status indicates that the rock unit either has not been sufficiently studied or lacks good exposures to warrant a definitive rating. This rating is treated initially as having a high sensitivity or potential. After study or monitoring, the unit may fall into one of the other categories.

The Museum of Paleontology at the University of California at Berkeley conducted a records search to identify known significant paleontological resources in the vicinity of the Center Road Pipeline, Line 225 Pipeline Loop, and Alternative Pipeline routes. Dr. Patricia Holroyd, a paleontologist representing the museum, reviewed their records and found that only one known fossil locality was present in the vicinity of the Center Road Pipeline and Alternative Pipeline routes (Holroyd, pers. comm. 2003, see Entrix May 2004). Locality V5697 is located in Beardsley Wash, approximately 1.3 miles (2.1 km) northeast (upstream) at MP 11.3. A single specimen of a proboscidean tibia was found in the late Pleistocene Las Posas Formation. One other mammal specimen in the museum collection was collected in the general area (Camarillo) from the same formation.

Geologic formations of similar age and depositional environment to the Las Posas Formation may be encountered near Beardsley Wash between MP 12.5 and MP 14.3. The remaining parts of the Center Road Pipeline and Alternative Pipeline Routes would be placed at a maximum depth of 7 feet (2.1 m) within recent alluvium (Figure 4.11-4), which has a relatively low probability of containing significant paleontologic resources.

Because the Line 225 Pipeline Loop appears to traverse similar non-marine sedimentary deposits (Loop MP 0.0 to MP 3) that have been identified to contain paleontological resources along the Center Road Pipeline Route (Figures 4.11-4 and 4.11-5), potentially significant paleontological resources may be present in the materials underlying that part of the Line 225 Pipeline Loop. However, a database search did not reveal any paleontological resources in the vicinity of the Line 225 Pipeline Loop.

4.11.2 Regulatory Setting

The Project will comply with all applicable laws, ordinances, regulations, and standards related to geologic hazards and resources during and following construction. Applicable laws, ordinances, regulations, and standards, which are summarized in Table 4.11-3, are not expected to change prior to the completion of this Project.

Table 4.11-3 Major Laws, Regulatory Requirements, and Plans for Geologic Resources

Law/Regulation/Plan/ Agency	Key Elements and Thresholds; Applicable Permits
Federal	
Hazards Analysis, (30 CFR 250.204 (b)(1)(viii) and CFR 250.1007 (a)(5) and shallow hazards survey (30 CFR 250.204(a)(17) and CFR 250.909) - *MMS*	• Perform an analysis of seafloor and subsurface geologic and man-made hazards of all areas considered for oil and gas pipelines. This includes identifying and evaluating conditions that might affect the safety of proposed operations or that might be affected by the proposed operations. This evaluation process depends primarily on interpretation of data obtained from appropriately designed and executed high-resolution geophysical surveys. • A shallow hazards survey and a geotechnical analysis of foundation soils/sediments underlying the proposed pipeline route must be performed.
State	
California Seismic Hazards Mapping Act of 1990 (Public Resources Code Section 2690 and following as Division 2, Chapter 7.8) an the Seismic Hazards Mapping Regulations (CCR Title 14, Division 2, Chapter 8, Article 10)	• Designed to protect the public from the effects of strong ground shaking, liquefaction, landslides, other ground failures, or other hazards caused by earthquakes. The act requires that site-specific geotechnical investigations be conducted identifying the hazard and formulating mitigation measures prior to permitting most developments designed for human occupancy. • Special Publication 117, Guidelines for Evaluating and Mitigating Seismic Hazards in California (California Department of Conservation (CDC), Division of Mines and Geology 1997), constitutes the guidelines for evaluating seismic hazards other than surface fault rupture, and for recommending mitigation measures as required by Public Resources Code Section 2695(a).
The California Coastal Act (CCA) of 1976 *- California Coastal Commission (CCC)*	• Preserves, enhances, and restores coastal resources. • Requires protection against loss of life and property from coastal hazards, including geologic hazards.
California State Lands Commission	• Requires that the pipeline meets current seismic standards such as the “Guidelines for the Design of Buried Steel Pipe,” American Lifeline Alliance, July 2001; “Draft Guideline for Assessing the Performance of Oil and Natural Gas Pipeline Systems in Natural Hazard and Human Threat Events,” American Lifeline Alliance, April 2004; and “Guidelines for the Seismic Design of Oil and Gas Pipeline Systems,” American Society of Civil Engineers, 1984.
Public Resources Code, Section 5097.5 (Stats. 1965, c. 1136, p. 2792) – *United States Environmental Protection Agency (USEPA); USCG*	• Defines any unauthorized disturbance or removal of fossil sites or remains on public land as a misdemeanor.

Table 4.11-3 Major Laws, Regulatory Requirements, and Plans for Geologic Resources

Law/Regulation/Plan/ Agency	Key Elements and Thresholds; Applicable Permits
Uniform Building Code (UBC)	• Contains requirements related to excavation, grading, and construction. Applicable codes and industry standards related to various geologic and soil features are identified in Appendix 8-3, Civil Engineering Design Criteria, UBC. The Project site is in the UBC and CBC Seismic Zone 4 (Uniform Building Code 1994, Volume 2 Structural Engineering Design Provisions); the requirements included in the UBC and CBC for Zone 4 shall apply to the Project, including consideration for ground acceleration in structural design to provide earthquake-resistant design. According to the CBC, a grading permit is required if more than 50 cubic yards of soil is moved. Chapter 33 of the CBC contains requirements relevant to the construction of pipelines alongside existing structures. CCR Title 23, Sections 3301.2 and 3301.3 contain the provision requiring protection of the adjacent property during excavations and requires 10 days written notice and access agreements with the adjacent property owners.
Warren-Alquist Act (Public Resources Code 25000 *et seq*.)	• The Warren-Alquist Act requires the Project site to be evaluated in unique areas of scientific concern (Section 25527).
Local Regulations	
Grading Permits *- Local City or County* *Other*	• Required when more than 50 cubic yards (38 cubic meters [m^3]) of soil is moved. • No local regulations or codes are applicable, beyond those identified in the UBC Appendix Chapter 33 related to excavation, grading, and construction.

The Alquist-Priolo Special Studies Zones Act of 1972 mitigates the hazard of fault rupture by prohibiting the location of structures for human occupancy across the trace of an active fault. The act does not specifically regulate pipelines, but it does help define areas where fault rupture is most likely to occur. This Act applies only to the terrestrial part of the Project. The act requires that "earthquake fault zones" be delineated by the State of California, i.e., by state geologists, along faults that are "sufficiently active" and "well-defined." These faults show evidence of Holocene surface displacement (sufficiently active) and are clearly detectable by a trained geologist (well defined). No Project components cross over an Alquist-Priolo Earthquake Fault Zone as defined by the California Division of Mines and Geology.

4.11.3 Significance Criteria

Significance criteria were determined based on California Environmental Quality Act Guidelines, Appendix G, Environmental Checklist Form. For the purposes of this EIS/EIR, geological resources impacts are considered significant if the Project:

- Worsens existing unfavorable geologic conditions;

- Exposes people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - Rupture of a known earthquake fault,
  - Strong seismic ground shaking,
  - Seismic-related ground failure, including liquefaction, or
  - Causes severe damage or destruction to one or more Project components as a direct consequence of a geologic event;
- Damages a pipeline due to landslide, lateral spreading, subsidence, liquefaction or collapse as a result of locating the Project on a geologic unit or soil that is unstable, or that would become unstable as a result of the Project;
- Releases toxic or other damaging material into the environment as a result of a geologic event;
- Releases toxic or other damaging material into the environment as a result of installation activities release of drilling muds during horizontal directional drilling (HDD);
- Exposes people or structures to potential substantial adverse effects, including the risk of loss, injury or death involving inundation by seiche, tsunami, or mudflow; landslides; flooding;
- Causes a significant increase of erosion during or after construction due to disturbance of sediment or soil;
- Causes a loss of a unique geologic feature or paleontologic resource;
- Deteriorates structural components of the port, subsea pipeline, terrestrial pipeline, or other land-based facilities due to corrosion, weathering, fatigue, or erosion that could reduce structural stability; and/or
- Damages pipelines and/or valves along the pipeways from any of the above conditions that could release natural gas into the environment.

4.11.4 Impact Analysis and Mitigation

The main concerns are not what impacts the Project could have on geology, other than paleontological and mineral resources, but rather how geologic processes could adversely impact the Project or the community.

Potential impacts on geologic resources and mitigation measures proposed for such impacts are discussed below. A summary of potential impacts on geologic resources and the proposed mitigation measures is provided in Table 4.11-4. Applicant-proposed mitigation measures (AMM) and agency-recommended mitigation measures (MM) are defined in Section 4.1, “Introduction to Environmental Analysis”.

Table 4.11-4 Summary of Geology Impacts and Mitigation Measures

Impact	Mitigation Measure(s)
GEO-1: Construction activities could temporarily worsen existing unfavorable geologic conditions (Class II).	**AMM GEO-1a. Drilling Location.** For HDD drilling at the shore crossing, the entry and exit points of the drilling would be outside of the area affected by normal storms. **MM GEO-1b. Backfilling and Compaction.** Proper backfilling and compaction, as defined by standard construction practices, comparable to existing conditions shall be done to prevent preferential flow paths, erosion, or subsidence. **MM GEO-1c. Design and Monitoring.** Proper design and monitoring of the drilling mud properties, and sufficient burial depth, shall be conducted to minimize the probability of the occurrence of a release of drilling muds. **MM GEO-1d. Trenching and Construction.** During trenching and construction activities, erosion control measures, such as straw bails, shall be implemented to keep water from entering the trench. **MM GEO-1e. Compacting and Grading.** Following installation of the pipeline system, the trench shall be compacted and graded to pre-existing contours and revegetated/restored to pre-existing conditions.
GEO-2: Construction activities could disturb or destroy paleontological resources; such impacts are typically permanent (Class II).	**MM GEO-2a. Inspection.** Paleontological inspection to be conducted prior to excavation in suspect areas; paleontological monitoring by qualified paleontologist during excavation.
GEO-3: Damage to pipelines or other facilities could occur due to direct rupture (ground offset) along fault lines (Class II).	**AMM GEO-3a. Fault Zone Avoidance.** Avoid crossing known active fault zones, where possible. **AMM GEO-3b. Pipeline Flexibility.** Install offshore pipelines directly on seabed. **MM GEO-3c. Geotechnical Studies.** Complete final geotechnical studies at suspected active fault crossings. **MM GEO-3d. Design and Operational Procedures.** Follow specified guidelines; ensure pipeline design includes evaluation of engineered fill, pipe wall thickness, shutoff valves, and seismic switches/alarms.
GEO-4: Damage to pipelines or other facilities could occur due to direct rupture (ground offset) along fault lines (Class II).	**MM GEO-4a. Design for Ground Shaking.** Complete proper seismic design; follow specified guidelines.
GEO-5: Mass movement, which is of a transitory and sporadic nature, could damage pipelines or structures (Class III).	**AMM GEO-5a. Avoid Areas of Mass Movement.** Avoid areas where soil is susceptible to mass movement and areas with steep slopes; design pipeline to withstand pressures resulting from mass movement and allow flexibility.
GEO-6: Tsunamis, which are transitory and sporadic in nature, could damage near-shore pipelines or facilities due to the typical force and erosive nature of these storms (Class III).	**AMM GEO-6a. Pipeline Burial.** Bury shore crossing pipelines to sufficient depth to avoid damage from tsunamis.
GEO-7: Damage to pipelines and/or other	None.

Table 4.11-4 Summary of Geology Impacts and Mitigation Measures

Impact	Mitigation Measure(s)
facilities due to shallow gas seeps along the pipeline route could threaten the structural integrity of the pipeline or facility system, although this impact is unlikely (Class III).	
GEO-8: A surface pipeline could have a short or long-term, minor impact on the natural flow of sediment parallel to the shoreline (Class III).	**MM GEO-8a. Pipeline Location and Burial to Avoid Sediment Transport.** Near shore section of pipeline will be buried; offshore pipeline route selected to avoid areas of sediment transport or be parallel to primary sediment transport direction.

Impact GEO-1: Increased Erosion, Differential Compaction, or Scour

Construction activities could temporarily worsen existing unfavorable geologic conditions (Class II).

Trenching and HDD activities could increase erosion, differential compaction, or scour, resulting in hazardous conditions for the pipeline along the pipeline route. The trenching or drilling could also provide preferential flow paths for fluids in the subsurface. During installation activities there could be transitory and sporadic erosion and scour. For example, such an impact could occur if there were a rainstorm during trenching. Exposure of the pipeline along the shoreline crossing due to storm activity could have local effects on nearshore sediment transport and turbidity.

The Applicant has incorporated the following measures into the proposed Project:

AMM GEO-1a. **Drilling Location.** For HDD drilling at the shore crossing, the entry and exit points of the drilling would be outside of the area affected by normal storms and the pipeline would be buried deep enough to prevent surfacing due to storm erosion.

Mitigation Measures for Impact GEO-1: Increased Erosion, Differential Compaction, or Scour

MM GEO-1b. **Backfilling and Compaction.** Proper backfilling and compaction, as defined by standard construction practices, comparable to existing conditions shall be done to prevent preferential flow paths, erosion, or subsidence.

MM GEO-1c. **Design and Monitoring.** Proper design and monitoring of the drilling mud properties, and sufficient burial depth, shall be conducted to minimize the probability of the occurrence of a release of drilling muds. Procedures shall be developed to mitigate any release of drilling muds that may occur and shall be documented in the HDD Contingency Plan. The Plan shall be submitted to USCG and CSLC for review and approval at least 60 days prior to commencement of HDD operations.

MM GEO-1d. **Trenching and Construction.** During trenching and construction activities, erosion control measures, such as straw bails, shall be implemented to keep water from entering the trench.

MM GEO-1e. **Compacting and Grading.** Following installation of the pipeline system, the trench shall be compacted and graded to pre-existing contours and revegetated/restored to pre-existing conditions.

With the implementation of these mitigation measures, this impact will be reduced to a less than significant level.

Impact GEO-2: Disturbing or Destroying Paleontological Resources

Construction activities could disturb or destroy paleontological resources; such impacts are typically permanent (Class II).

As discussed above, there are several areas along the Center Road Pipeline and Line 225 Pipeline Loop that are tentatively classified as having a high sensitivity of containing significant paleontological resources.

<u>Mitigation Measure for Impact GEO-2: Disturbing or Destroying Paleontological Resources</u>

MM GEO-2a. **Inspection.** A paleontological inspection shall be completed prior to excavating in the suspect areas, between Center Road Pipeline MP 12.6 and MP 14.3 in Beardsley Wash, and Line 225 Pipeline Loop from Loop MP 0.0 to MP 3.5 and MP 6.7 and MP 7.7. Paleontological monitoring of excavations in these areas shall be undertaken by a qualified paleontologist based on the findings of the inspection. The paleontologist shall provide education and training of construction workers about potential paleontological resources that may be discovered and, subject to prior approval by the CSLC, he/she shall have the ability to stop construction if potentially significant resources are identified and threatened by the Project. All specimens collected from public land shall be deposited at a curating institute such as the University of California.

With the implementation of this mitigation measure, this impact will be reduced to a less than significant level.

Impact GEO-3: Damage Due to Direct Rupture along Fault Lines

Damage to pipelines or other facilities could occur due to direct rupture (ground offset) along fault lines (Class II).

An earthquake can cause significant surface displacement along its surface trace. For example, the 1971 San Fernando (Sylmar) quake had measured offset of up to 6.2 feet (2 m) and the 1992 Landers quake, located in the Mojave Desert, had offsets of up to about 19 feet (6 m). However, there is no fault rupture from most earthquakes. Substantial displacement could cause a rupture of a pipeline.

Welded steel pipelines can be designed to withstand substantial fault movement without rupture when the direction, location, and magnitude of anticipated offset is well defined. However, significant fault rupture (such as occurred in the 1992 Landers or 1906 San Francisco quakes which had offsets of 19 feet [6 m] or more) could result in pipeline rupture even if all protective design measures are implemented. An earthquake performance study was conducted on steel gas transmission and supply lines operated by Southern California Gas Company over a 51-year period (1945 through 1996). This study found that post-1945 arc-welded transmission pipelines in good repair have never experienced a break or leak during a southern California earthquake (O'Rourke and Palmer 1996). Pipeline breaks have occurred but apparently they were on older pipe, pipe that was not arc welded, or on pipe in poor repair.

The CSLC requires the incorporation of current seismological engineering standards such as the *Guidelines for the Design of Buried Steel Pipe* (American Lifeline Alliance), *Guidelines for the Seismic Design of Oil and Gas Pipeline Systems* (American Society of Civil Engineers), and other recognized industry standards for seismic-resistant design at all fault crossings.

The Applicant has incorporated the following into the proposed Project:

AMM GEO-3a. **Avoidance.** The primary mitigation measure shall be to avoid, where possible, crossing known active fault zones. The Project has avoided known fault crossings, but this is a seismically active area and the pipeline route likely crosses several buried faults as discussed in Section 4.11.1.2, both on and offshore.

AMM GEO-3b. **Pipeline Flexibility.** The Applicant shall install the offshore pipeline directly on the seabed surface. This shall allow enhanced flexibility of the pipeline, when compared to a buried pipeline, to deal with movement caused by fault rupture. Under normal conditions (not due to mass movement) some sediment may cover the pipeline but this minor sediment should not affect the flexibility of the pipeline.

<u>Mitigation Measures for Impact GEO-3: Damage Due to Direct Rupture along Fault Lines</u>

MM GEO-3c. **Geotechnical Studies.** A preliminary seismic hazard evaluation was completed that included some technical modeling (Fugro 2004). A Final site-specific seismic hazard study shall be completed and approved by the CSLC and United States Coast Guard (USCG) prior to construction.

For suspected onshore pipeline crossings (discussed in Section 4.11.1.2) of faults the Applicant shall complete final geotechnical studies at suspected active fault crossings to accurately define the fault plane location, orientation, and direction of anticipated offset. It shall include the magnitude of the anticipated offset at the fault locations. This information shall be used to refine fault crossing design parameters. It is best to orient the pipe at fault crossings to produce tension in the pipe if there is ground rupture along the fault. Compression of the pipe is more likely to cause pipe rupture than tension. This site-specific seismic hazard study shall be completed and approved by CSLC and USCG prior to construction.

MM GEO-3d. **Design and Operational Procedures.** The above-mentioned *Guidelines for the Design of Buried Steel Pipe* and *Guidelines for the Seismic Design of Oil and Gas Pipeline Systems* shall be followed. The final pipeline design shall include evaluation of, but not limited to, engineered backfill, thicker wall pipe, shutoff valves placed on either side of fault crossings, and seismic switches/alarms.

Adherence to these mitigation measures would reduce this impact to a less than significant level.

Impact GEO-4: Damage to Pipelines and Associated Facilities from Surface Shaking

Ground shaking from earthquakes, which is of a transitory and sporadic nature, could damage pipelines or associated facilities (Class II).

Strong earthquake-induced ground shaking could result in significant damage to aboveground structures and lead to failure of open trenches during construction. Ground shaking generally impacts buried modern welded pipelines only when the shaking induces mass movement such as liquefaction, differential settlement, or landslides. Pipe damage also may result from transient ground deformation caused by the peak ground velocity of the seismic wave. However, the O'Rourke and Palmer study found that welded steel transmission pipe is highly resistant to traveling ground waves. The impacts of mass movement are discussed below.

- The impacts due to differential settlement typically occur at transitions between stiff and soft soils; and
- The aboveground structures, such as the offshore part of the pipelines or the onshore processing facilities, are subject to strong ground shaking.

<u>Mitigation Measure GEO-4: Damage to Pipelines and Associated Facilities from Surface Shaking</u>

MM GEO-4a. **Design for Ground Shaking.** Proper seismic design will allow pipelines and other structures to withstand intense ground shaking without collapsing. These designs shall include the *Guidelines for* *the Design of Buried Steel Pipe*, *Guidelines for the Seismic Design of Oil and Gas Pipeline Systems,* and the American Society of Mechanical Engineers (ASME 2001) *Managing System Integrity of Gas Pipelines*.

Adherence to this mitigation measure would reduce this impact to less than significant.

Impact GEO-5: Damage to Pipelines from Landslides, Liquefaction, Subsidence, Sand Migration, or Turbidity Currents

Mass movement, which is of a transitory and sporadic nature, could damage pipelines or structures (Class III).

Ground shaking or other processes may cause mass movement. During loss of ground bearing capacity, such as with liquefaction, large deformations can occur within the soil mass, allowing structures to settle or tilt. A large enough movement could cause pipeline rupture. Liquefaction of a buried layer may result in substantial lateral spreading of overlying competent soil. A good example of lateral spreading occurred during the 1971 San Fernando (Sylmar) earthquake, when an area of almost 163 acres (66 hectares [ha]) moved down a 2.5 percent slope. In addition, lateral spreading was responsible for most of the water pipeline failures in San Francisco during the 1989 Loma Prieta earthquake.

The offshore pipeline routes have been selected to take advantage of gentle slopes and areas that are more stable. The Hueneme-Mugu Shelf in the vicinity of the Project is considered stable based on the low-angle slopes of about 0.3 to 0.4 percent and the lack of direct evidence of previous instability. Evidence of submarine slides has been recorded in the general vicinity of the Project along the Hueneme-Mugu Slope and within the associated submarine canyons. Also, the Hueneme and Mugu Canyons are considered active sediment transport areas, transporting sediment from the nearshore shelf to the basin floor via turbidity flows. The Project route does not overlie areas with previously identified slump movement or in canyons where turbidity flows are most likely to occur, but the route is along a slope that is susceptible to creep. The area considered to have the highest liquefaction potential along the offshore part of the Project is on the shallow shelf near the onshore landing. It is in that location that the thickest deposits of potentially liquefiable material are expected. The maximum depth of liquefaction is anticipated to be around 22 to 32 feet (7 to 10 m) (Fugro 2004).

Most of the onshore parts of the pipelines are in areas that are considered to have liquefaction potential due to the granular soils and shallow water table. However, the route does have gentle slopes. Some of the Line 225 Pipeline Loop route is in areas with landslide potential.

In addition, the Applicant would be required to construct the pipelines and facilities in accordance with all applicable standards and regulations. The USCG and CSLC will only issue their permit/license after additional geotechnical reports have been completed and a strict set of design criteria have been established.

The applicant has incorporated the following measure into the proposed Project:

AMM GEO-5a. **Avoid Areas of Mass Movement.** To the extent possible, areas of soil susceptible to mass movement and areas of steeper slopes shall be avoided by the Applicant. The pipeline shall be designed to withstand potential pressures due to mass movement and to allow flexibility should movement occur.

Mitigation Measure GEO-5: Damage to Pipelines from Landslides, Liquefaction, Subsidence, Sand Migration, or Turbidity Currents

Adherence to the applicable standards and permit/license conditions as well as the AMM described above would reduce this impact to less than significant.

Impact GEO-6: Damage to Pipelines from Tsunamis

Tsunamis, which are transitory and sporadic in nature, could damage near-shore pipelines or facilities due to the typical force and erosive nature of these storms (Class III).

There is little risk of damage from tsunamis to facilities located in deep water, but significant erosion, high current, and wave forces can occur in shallow water near the shore. This impact is considered less than significant.

The Applicant has incorporated the following into the proposed Project:

AMM GEO-6a. **Pipeline Burial.** The pipeline at the shore crossing would be buried deeply enough to avoid potential damage from tsunamis.

Mitigation Measure for Impact GEO-6: Damage to Pipelines from Tsunami

This impact is less than significant and no additional mitigation is identified.

Impact GEO-7: Damage to Pipelines from Shallow Gas Seeps

Damage to pipelines and/or other facilities due to shallow gas seeps along the pipeline route could threaten the structural integrity of the pipeline or facility system, although this impact is unlikely (Class III).

Natural gas may be present in marine sediments. The presence of gas bubbles in the pore space of sediments can increase pore pressure and reduce the shear strength of the sediment, and thus increase the likelihood of mass movement. Under some circumstances, sediment containing dissolved gas can liquefy spontaneously when it is subjected to cyclic loading such as could be caused by earthquake shaking (Hall and Ensiminger 1979; Kennedy et al. 1987, as seen in Entrix August 2003).

Based on intermediate- to high-resolution seismic records, gas seeps have not been identified beneath the Project area (Kennedy et al. 1987, as seen in Entrix August 2003).

This impact is not considered significant.

Mitigation Measure for Impact GEO-7: Damage to Pipelines from Shallow Gas Seeps

This impact is less than significant and no additional mitigation measures are identified.

Impact GEO-8: Potential to Change the Transport of Sediment in Offshore Areas

A surface pipeline could have a short- or long-term, minor impact on the natural flow of sediment parallel to the shoreline (Class II).

Mitigation Measure for Impact GEO-8: Potential to Change the Transport of Sediment in Offshore Areas

MM GEO-8a. **Pipeline Location and Burial to Avoid Sediment Transport.** The nearshore section of the pipeline shall be buried and thus shall not affect sediment transport. Further offshore the pipeline route shall avoid areas of sediment transport or to be parallel to the primary transport direction (down slope) to the extent practicable.

With the implementation of this mitigation measure, this impact is less than significant.

4.11.5 Alternatives

4.11.5.1 No-Action Alternative

Under this alternative, the impacts described in this section would not occur.

4.11.5.2 Alternative DWP Location - Santa Barbara Channel/Mandalay Shore Crossing/Gonzales Road Pipeline

The Santa Barbara Channel/Mandalay Shore Crossing/Gonzales Road Pipeline Alternative is subject to similar regional and local geologic hazards, including ground shaking, mass movement and erosion, liquefaction, tsunamis, and shallow gas seeps as the proposed Project location and has essentially the same impacts and impact classes as the selected route. The chance of damage from direct fault rupture in offshore areas may be somewhat less. However, the Alternative location is nearer the estimated location of the epicenters of the large 1812 and 1925 Santa Barbara earthquakes.

4.11.5.3 Alternative Onshore Pipeline Routes

Center Road Pipeline Alternative 1

The Center Road Pipeline Alternative 1 is farther from the Springville Fault Special Studies Zone and is less likely to cross this fault. All other impacts/hazards, including paleontological resources, ground shaking, liquefaction, and increased erosion, are essentially the same as for the proposed route. Impact classes are identical.

Center Road Pipeline Alternative 2

Generally, impacts associated with this Alternative are similar to those of the proposed route, and impact classes are the same. The Center Road Pipeline Alternative 2 is closer to the Springville Fault Special Studies Zone and is more likely to cross this fault. All other impacts/hazards, including paleontological resources, ground shaking, liquefaction, and increased erosion, are essentially the same as for the proposed route.

Line 225 Pipeline Loop Alternative

The Line 225 Pipeline Loop Alternative route is subject to nearly identical regional and local geologic hazards as the proposed Line 225 Pipeline Loop route, including paleontological resources, seismic hazards, liquefaction, and increased erosion. Impacts and classes are the same as those identified for the proposed route.

4.11.5.4 Alternative Shore Crossings and Pipeline Connection Routes

Point Mugu Shore Crossing/Casper Road Pipeline

The geologic impacts from the Point Mugu Shore Crossing/Casper Road Pipeline Alternative, including paleontological resources, seismic hazards, threat from tsunamis, liquefaction, and increased erosion, are essentially the same as those identified for the proposed route. Impacts and classes are the same as those identified for the proposed route.

Arnold Road Shore Crossing/Arnold Road Pipeline

The geologic impacts from the Arnold Road Shore Crossing/Arnold Road Pipeline Alternative, including paleontological resources, seismic hazards, threat from tsunamis, liquefaction, and increased erosion, are essentially the same as those identified for the proposed route. Impacts and classes are the same as those identified for the proposed route.

4.11.6 References

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